Building Research Establishment Digest

CI/SfB 1976 (53·15)	DIGEST 205

September 1977

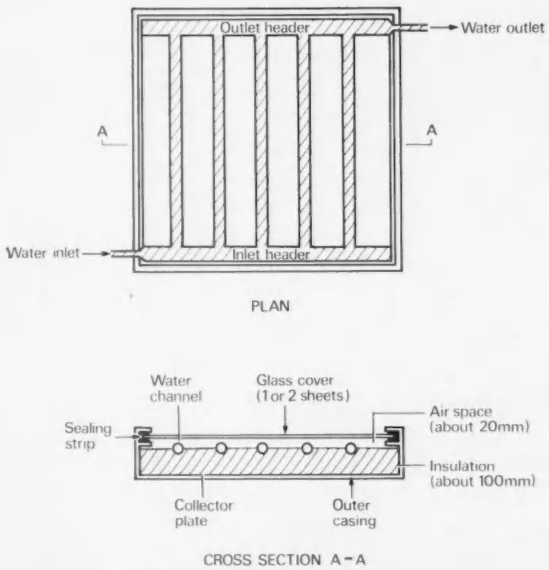
Domestic water heating by solar energy

Although in the UK a solar system can only augment a conventional domestic water heater, there is increasing interest in the use of solar energy and a number of firms are now marketing equipment. This digest describes briefly how solar water heating systems work and draws attention to potential problems which can be avoided in design; however, development is still at an early stage and there is little experience on which to base estimates of long-term performance and economics of solar systems.

Physical principles

A typical collector module is shown in Fig 1. Short wavelength solar radiation incident on the panel is transmitted through the glass and is absorbed on the black surface of the collector plate, raising the temperature of both the plate and any fluid circulating through the water channels. Most of the long wavelength radiation emitted by the plate when warm is retained within the assembly because glass transmits such radiation badly. Some heat is, however, lost in this way and some by conduction through the insulation behind the plate. Hence the operating efficiency of a solar panel decreases as the plate temperature rises.

Fig 1 Typical solar water heating panel



System design

A simple system using natural circulation is shown in outline in Figure 2. As the temperature of the water in the panel rises, its density decreases thus establishing a circulation and the water in the cylinder is progressively heated. For efficient performance however, the vertical distance between the top of the panel and the bottom of the cylinder should be at least 300 mm and, particularly if the collector is mounted on a roof, this may not be convenient to arrange. It is therefore more usual for a small electric circulating pump to be incorporated in the circuit; this enables the storage tank to be placed in any convenient location although it should be as close as possible to the collector to minimise both heat losses and pumping costs. The pump should be controlled by a circuit which senses the temperature difference between the water in the collector and the cylinder; water will then only be circulated when useful heat may be gained.

Natural circulation, however, has the advantage of simplicity in design and fewer maintenance problems than a pumped system. Circulation occurs only when solar input is sufficient to heat the water in the panel to a temperature greater than the water in the cylinder and, provided the bottom of the cylinder is at least 600 mm above the top of the panel, there should be no reverse flow when there is no solar input.

Double glazing improves the heat retention properties of the unit but about twice as much of the incident radiation is reflected and absorbed before reaching the collector plate and the net benefit is marginal in a domestic water heating installation in the UK. Double glazing is indeed disadvantageous when the average water temperature is low, when heating a swimming pool for example. The collector plate is usually of steel, copper or aluminium construction with the water channels formed by pressing from sheet or with welded tubes. Non-metallic collectors have been used; their profiles must be different from that shown

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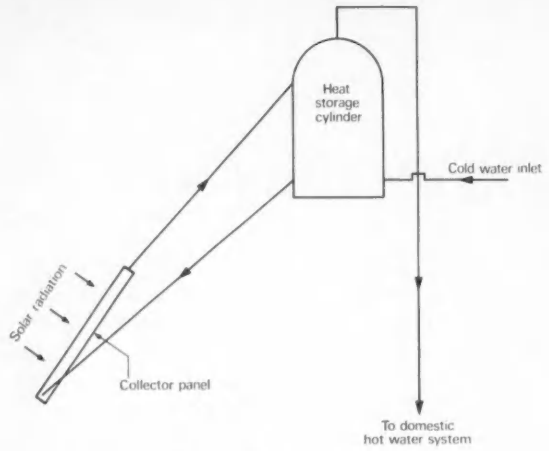


Fig 2 Simple solar collection system

in Fig 1 because the thermal conductivity of plastics is much less than that of metals.

Freezing may occur in the collector in winter if a 'direct' system such as that shown in Figure 2 is used. This can be avoided by replacing the heat storage cylinder with an 'indirect' cylinder of conventional design; anti-freeze and corrosion inhibitors may then be added to the water that circulates through the collector.

Whilst Figure 2 shows the simplest means of collecting solar energy, a system offered as a complete package is likely to be more complex; a typical layout is shown in Fig 3. When the temperature at the outlet of the panels exceeds that of the bottom of the solar cylinder by more than a preset amount (usually 2–3°C), the circulating pump is switched on by the control unit and the water in the solar cylinder is heated until insufficient temperature difference is detected between points A and B. The water passing into the conventional cylinder is thus warm and less heat has to be supplied by conventional means to raise its temperature to the desired value, probably about 55°C. A correctly-designed solar system will even provide water on a few days in summer at the required tap temperature and no further heating will be required.

Heating panels Ideally they should face the noon sun but their exact orientation is not critical, any convenient direction in the SE–SW quadrant being satisfactory; shading by adjacent buildings or trees should be avoided if possible. The panels should slope at between 20° and 60° to the horizontal but, again, the exact angle of inclination is not a critical factor. A normal domestic installation will require 4 to 6 m² of panel area or about 1 m² for every 50 litres of daily hot water demand. The total panel area is the most important factor in determining the heat collected annually.

The water circulation rate should be in the range 35 to 70 litres per hour for every m² of panel and the flow should be equal through each panel.

Solar cylinder A conventional indirect cylinder of about 200 litres capacity will be suitable for a domestic installation with about 4 m² of panel; the cylinder and all connecting piping should be well insulated. Cylinders are now available with two indirect coils, the lower for solar-heated water and the upper for connection to a conventional boiler. These are convenient if space is limited since only one cylinder is required.

Expansion volume As in a domestic central heating system, provision must be made for expansion of the water. This may take the form of a header tank at the highest point in the system, or a diaphragm expansion volume may be used. The latter is normally the easier to accommodate when panels are roof mounted and, for a domestic system, would need a volume of two to five litres capacity depending on the water capacity of the panels. It is advisable to incorporate a 'deadleg' between the expansion volume and the solar circuit to reduce the temperature of the water in contact with the diaphragm.

One-way valve The temperature of the panels will often fall below that of the solar cylinder at night and reverse circulation, which will cool the cylinder, can take place if a one-way valve is not fitted. If it is situated at other than the lowest point in the system, a drain-cock should be fitted immediately above it.

Air vent As in a domestic central heating system, an air vent is required at the highest point in the system to release air-locks during filling and pressurising. An automatic airvent, normally float-operated, will obviate the need to purge air from the system during its first months of operation.

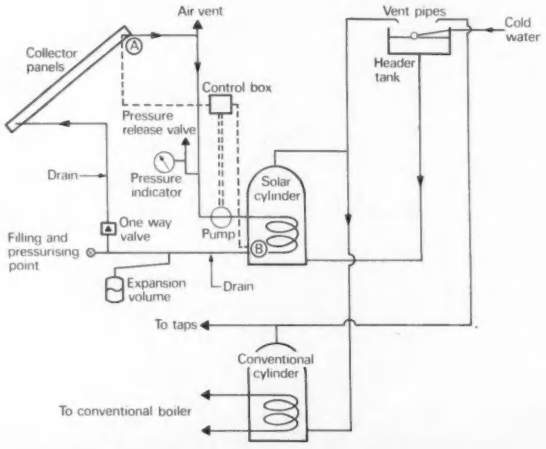


Fig 3 Pumped, indirect solar water heating system

Control unit These are now available complete with the necessary temperature detectors, which must be installed so that the water temperature, and not the ambient temperature, is sensed.

Two other components, not shown in Figure 3, may be considered desirable.

Maximum temperature controller The temperature in the solar cylinder may rise above a safe level if no water is drawn off in heat-wave conditions. A small fan-cooled heat exchanger can be fitted in the solar circuit, controlled by a temperature detector, to ensure that the temperature in the solar cylinder is never excessively high.

Automatic make-up unit (for sealed systems) Some fluit may escape from the system as a result of over-heating or minor leaks; this unit enables the interval between inspections to be increased.

Corrosion
The use of dissimilar metals in a plumbing system can cause corrosion. In a solar system, the main risk occurs when aluminium panels are used with copper tube; pitting corrosion of the panels can take place even in the absence of physical contact of the two metals. Precautions which can be taken include the use of corrosion inhibiter in the water circulating through the panels but it may be preferable to use a sealed circuit filled with distilled water and suitable anti-freeze. The long-term effectiveness of such precautions is, however, not yet reliably established and systems with aluminium panels should be regularly examined for leaks. Steel panels can be used with more confidence in indirect systems because of the experience gained in domestic central heating systems. Copper panels are, of course, completely compatible with copper tube.

Freezing
In an indirect system, such as that shown in Figure 3, anti-freeze (of a type approved by the local water authority) can be added to the water which circulates through the panels. Both direct and indirect systems can be designed in which the panels drain whenever the pump is switched off but this is not normal practice because the fresh water continually being circulated through the panels can form scale and impair the efficiency of the panels. Special anti-freeze solutions (to BS 3150) are available for use with aluminium but their service life is limited to between two and five years after which time the solution should be renewed. The use of a heat transfer oil is an attractive answer to problems of both freezing and boiling but information on this is lacking at present.

Boiling
The fluid in the system may boil if failure occurs in the pump or control unit or if no water is drawn off for a long period in summer. As more efficient panels are developed, this risk will increase. A pressure valve is a necessary safety precaution in a sealed system and may be conveniently combined with a pressure indicator to check that there are no leaks in the system. The outlet of the valve should be connected via an atmospheric break to a suitable drain point or container. In an 'open' system, where a header tank is used, no pressure release valve need be fitted.

Installation
The prime requirements when panels are mounted on an existing pitched roof are clearly that they should remain fixed under all conditions and that the roof should remain weathertight. Because of the many differences in construction of both panels and roofs, it is impossible to give detailed fixing techniques but some important considerations can be mentioned. If the panel is to be mounted on top of the roof covering, the roof must remain structurally safe with regard to the fairly considerable extra weight. In this situation, panels with aluminium casings might suffer corrosion from contact with new concrete roof tiles and the panels are at risk in high winds unless very securely fixed. The weight of the panels will be less of a problem if tiling is removed and the panel is fixed either on top of, or between, the rafters. This will also reduce the risk of condensation between panel and tiling causing corrosion attack but it creates problems of maintaining weathertightness. Careful attention must be paid to weatherproofing, the panels being treated as if they were skylights and flashed into the roof. In new houses it might be a cheaper alternative to build the panel assembly from its component parts and cover it with patent glazing. By this means, it might be possible to arrange for accessibility from within the roof space for maintenance although this is difficult with lower-pitched roofs. It will usually be easier to make the construction weathertight (at least at the bottom edge) if the panels are positioned in the lower part of the roof; this will also aid maintenance, especially glass cleaning which becomes more important with lower-pitched roofs because of the greater risk of dirt building up on the surface. Fitting a panel on top of the tiling in the lower part of the roof may introduce problems of rain water overshooting the gutter but a small upstand at the bottom of the panel may prevent this.

Legal requirements
There are at present no specific legislative controls over solar heating systems as such, but any installation must comply with the Building Regulations, Water Bye-laws and planning or other relevant controls. The responsibility for administering and interpreting the Building Regulations rests with the local authorities and it is necessary to contact the appropriate council at as early a stage as possible before starting work.

On the planning side, which is quite separate and distinct from control under the Building Regulations and Water Bye-laws, permission might also be

required from the local authority for an installation if, for example, it affected the external appearance of a building. The local planning authority would be able to advise on particular cases.

The Building Regulation and planning controls do not contain all the statutory requirements which may have to be complied with when a building is erected, altered or extended; again the appropriate local authority would be able to advise.

Performance

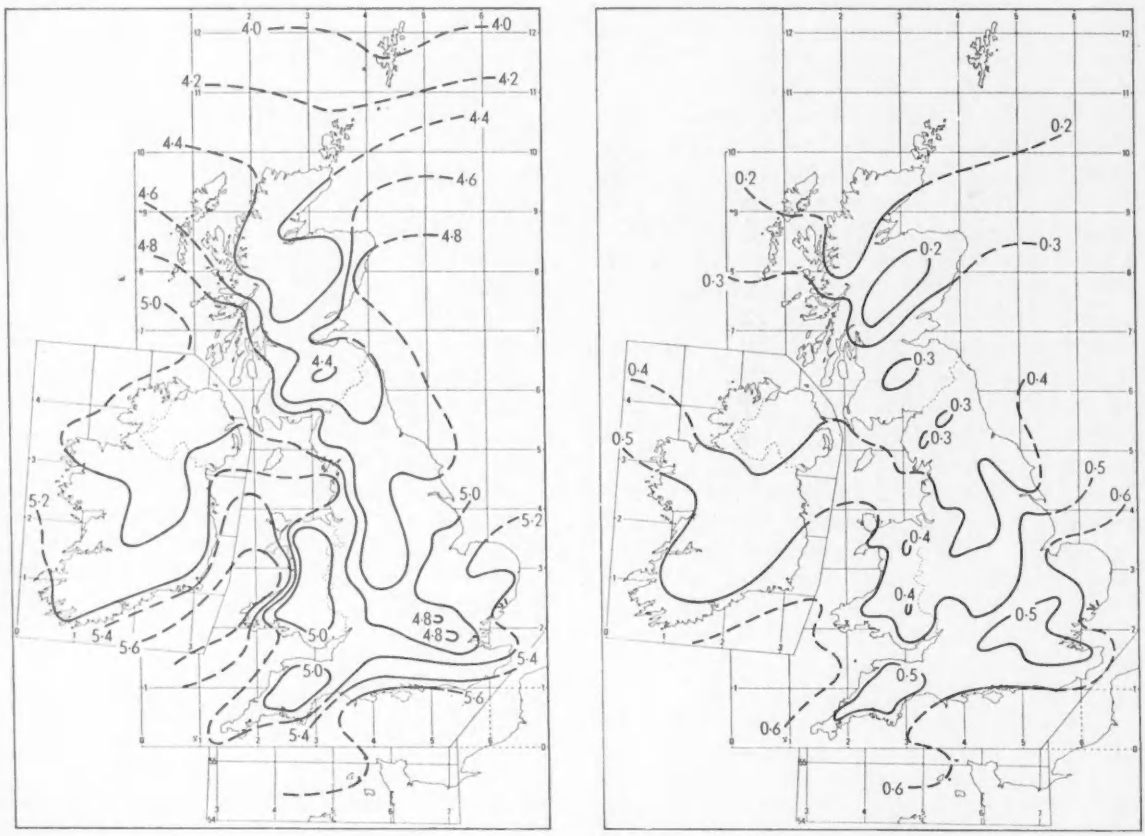
In the United Kingdom about 3.5 GJ* of solar radiation are incident in an average year on each m² of south-facing roof, obviously with far more during summer than winter (see Figures 4 and 5) and with rather more to the west of the country. A domestic solar water heating system with 4 m² of panel area may be expected to operate at an annual efficiency of about 35 per cent and so will supply about 5GJ (1400 kW hours or 48 therms) of heat over the year; this is 40 per cent of the domestic hot water requirements of the average household. With 6 m² of collectors, about 6.5 GJ will be obtained. Against this must be set about 0.5 GJ of electricity used annually by the pump. The useful heat supplied is not proportional to the area of panels because an increase in panel area will lead to the system operating on average at a higher temperature and therefore at a lower collection efficiency. Any heating system will require regular maintenance and the cost of this work will have to be considered in an economic assessment.

* 1 Gigajoule = approximately 278 kW hours or 9.5 therms.

Further reading

An appraisal of solar water heating in the UK; R G Courtney; BRE Current Paper CP 7/76
Solar energy utilisation in the UK: current research and future prospects; R G Courtney; BRE Current Paper CP 64/76
Energy consumption and conservation in Buildings; BRE Digest 191

Figs 4 and 5 Global solar radiation; average daily totals for June and December in kWh/m² (1kWh = 3.6 MJ)



Department of the Environment **Building Research Establishment**

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Single copies 10p each. Annual subscription inclusive of postage £2.25 for 12 monthly issues and new editions of earlier Digests. Quantity rates (excluding postage) for bulk supply of any one Digest: 50 for £4.

Dmd. 587252 K 592 7/77 ISBN 0 11 724117 2